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Field Studies of Geomembrane Installation Techniques

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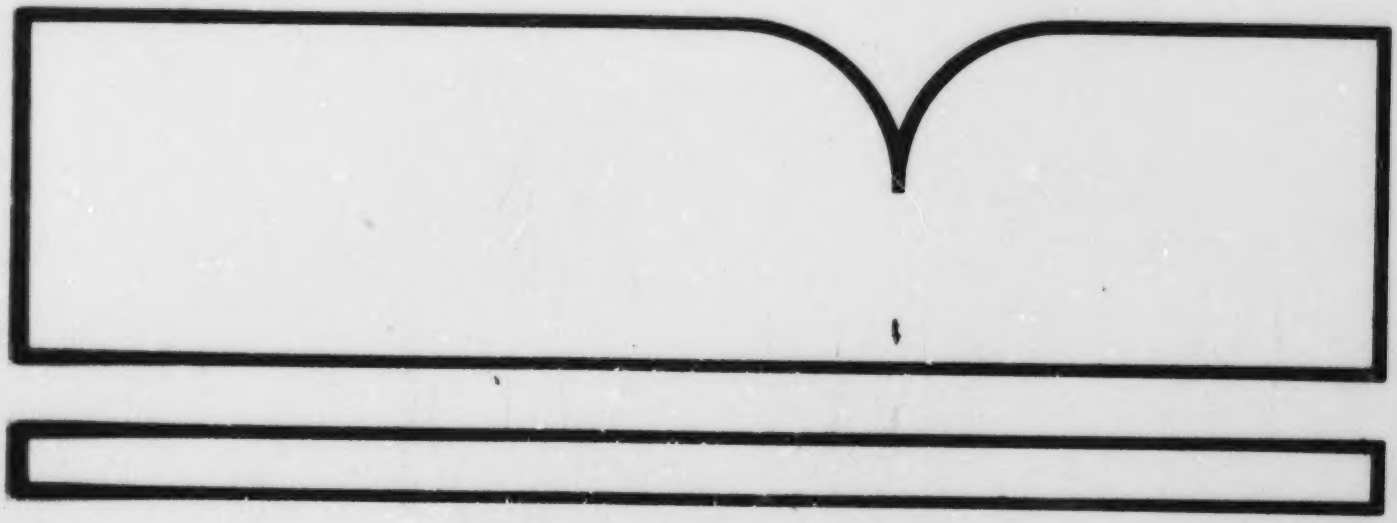

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FIELD STUDIES OF GEOMEMBRANE INSTALLATION TECHNIQUES

by

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16. ABSTRACT

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Six generic types of geomembrane materials were included in this study. They were (1) polyvinyl chloride (PVC); high density polyethylene (HDPE); (3) chlorosulfonated polyethylene (CSPE); (4) chlorinated polyethylene (CPE); (5) Neoprene®; and (6) ethylene propylene diene monomer (EPDM). Observed subgrade preparation procedures and geomembrane installation techniques are described in this paper.

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SUMMARY

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INTRODUCTION

Geomembranes are presently being used to contain fluids in hazardous waste surface impoundments and landfills. They function as a low permeability barrier to fluid flow. Many factors contribute to the overall effectiveness of the geomembrane system.

The proper planning, design, and construction of lined containment facilities involve numerous steps, including the following:

(1) Defining facility function and geometry;

(2) Designing a liner system that is compatible with the substances to be stored or treated;

(3) Planning suitable subgrade preparation, seepage monitoring, and collection systems (if appropriate);

(4) Planning proper liner installation; and

(5) Developing appropriate post-installation operation, maintenance, and closure plans.

This paper describes subgrade preparation techniques and placement procedures for geomembrane liner materials observed during a study performed by Southwest Research Institute for the U.S. EPA.

FIELD OBSERVATIONS

Fourteen construction sites where geomembranes were being installed were visited during the study. The type of facility and type of liner for each site is shown in Table 1. The installation of geomembranes requires proper planning before construction. Important elements of installation are adequate subgrade, onsite storage of materials, installation equipment, manpower requirements, procedures for liner placement, field seaming procedures, sealing around structures or penetrations, quality assurance/quality control procedures and soil cover requirements. Observations made at these sites regarding each of the major elements of installation procedures are described in the following sections.

Subgrade Considerations

For an earthen structure, the subgrade must be firm and dry, free of all rocks, roots, debris, or other objects that might tear or puncture the liner. Backfilling is recommended if necessary to meet these conditions. Where vegetation has been cleared to prepare the site, or soil has been brought in to provide a bed for the liner, soil sterilization is specified to prevent grasses from growing through the liner. This is especially true in areas where prior growths of nut or quack grasses have existed. Areas where excavated soil is deposited to create subgrade may also require sterilization.

TABLE 1. GEOMEMBRANE LINER CONSTRUCTION SITES VISITED DURING THE STUDY

Facility Type	Liner Type
Mine Tailings Storage	Polyvinyl chloride/chlorosulfonated polyethylene
Municipal Landfill	Polyvinyl chloride
Evaporation Pond	High density polyethylene
Potable Water Storage	Chlorosulfonated polyethylene
Brine Storage	Chlorinated polyethylene
Tailings Storage	Chlorosulfonated polyethylene
Potable Water Storage	Chlorosulfonated polyethylene
Evaporation Pond	Chlorinated polyethylene
Hazardous Waste Landfill	Chlorosulfonated polyethylene/clay soil
Spill Containment	Neoprene®
Industrial Waste Storage	Ethylene polyethylene diene monomer
Municipal Landfill Cover	Polyvinyl chloride
Municipal Wastewater Storage	Chlorosulfonated polyethylene
Spill Containment	Polyvinyl chloride

Compaction of the subgrade is normally specified to provide a firm support for all membrane lining materials. Generally, a fill subgrade is built up in a series of compacted layers, whereas an excavated subgrade is compacted only at the surface. Usually, the minimum compaction of the subgrade material will be specified. Most liner installations specify that the density of the subgrade be at least a specified percentage of that obtainable by the Standard Proctor Test, ASTM D698, with 90 percent of Proctor being the most frequently specified relative compaction. Some contracts will specify the compaction equipment which is to be utilized, number of equipment passes per layer, layer thickness, permissible water content range at placement, and method and location of water addition.

The regularity and texture of the surface is critical to a successful liner installation. A plane surface is the most desirable for liner placement, but is not always achievable or specified. In many installations, soil clods or local surface irregularities will be flattened (further compacted) by the overlying weight of the stored material after the facility is filled. Further, it is thought that the polymeric membrane liners will adjust their shape over any clods so that no detrimental effects will result. Nevertheless, rocks or irregularities with sharp edges should be eliminated from the finished subgrade prior to liner installation.

Compaction densities were at least 90 percent of Proctor for all but one installation listed in Table 1. In this installation, soil was placed over compacted refuse. A liner was then installed to prevent rainfall infiltration.

The installation contractor at the second facility, a municipal landfill, covered sharp sandstone subgrade with a geotextile before liner placement. The fabric served as a substitute for a sand bed.

Three facilities incorporated a cushioning medium over the native subgrade. At the second facility, 0.15 m (0.5 ft) of sand was placed over a rough sandstone. At the fourth and tenth facility, 0.30 m (1.0 ft) of sand was placed over concrete subgrades prior to liner placement. Liner installation

was performed at three sites where the subgrade was saturated. However, the liner was not installed over standing water at any of these sites. Soil sterilization was accomplished at two of the 12 sites with earthen subgrades. At both of these locations, vegetation had existed prior to excavation. The subgrade at the eighth installation was not sterilized and, subsequent to liner placement, salt grass grew through the liner, necessitating significant liner repair.

Onsite Storage of Material

Membrane materials are normally shipped to a construction site, and must be stored prior to placement. Most materials are folded in panels and shipped on wooden pallets or in rolls. Protection of the liner materials from the effects of heat and from vandalism is recommended. These are the two most important storage considerations. Excessive heating can degrade the surface of the material, causing problems with field bonding. Covering the material with white plastic or storing out of direct sunlight is recommended for all materials. If the material is shipped in cardboard boxes, plastic shielding is not required. Placing the material in a secure area is recommended to prevent vandalism.

Onsite storage of liner material was observed at eight of the fourteen sites visited. All of these sites were being constructed within a secured area. Therefore, storage of material at the impoundment site was considered to be in a secure area. Protection from direct sunlight was provided at two sites. Field crew members at the remaining sites indicated protection was not needed due to either the short time between delivery of the material and placement, or existing ambient temperatures did not warrant protection.

Installation Equipment

Equipment often required to install a membrane liner includes a fork lift truck, backhoe, or front end loader for material placement, and various tools necessary for material positioning and field seaming. A fork lift truck with large rubber tires (not warehouse type), is most often recommended for material placement, because most material is shipped to a site on wooden pallets. The pallets can easily be maneuvered with a fork lift truck.

The equipment needed to seam the material together is basically similar for all types of material, with the exception of high density polyethylene. Table 2 lists the equipment commonly used by the industry. High density polyethylene is welded together and requires special equipment.

Manpower Requirements

Manpower requirements for the installation of liner materials is a function of the rate that the installer wants to place panels and accomplish field seaming. Typically, installation contractors will recommend five to ten people onsite when placing one panel at a time. Generally, a crew foreman will direct the activities of the field crew. He may not directly participate in the unrolling and positioning of panels or in field seaming. However, it is recommended that he be experienced in the installation of the specific liner material.

TABLE 2. EQUIPMENT AND MATERIALS FOR INSTALLATION OF GEOMEMBRANE LINERS

Item	Use
Fork lift truck	To move liner panels into position.
Backhoe	To backfill anchor trenches.
Tires, sandbags	To anchor unseamed panels to prevent wind damage.
Proper adhesives	To make field seams and seal liner around concrete or steel penetrations.
Portable electric generator	To operate heat guns or lighting for working at night.
Air lance	Quality control testing of field seams.
Hand-held earth tampers and rakes	To smooth and compact subgrade as necessary.
Ladders	For access to side walls/steep slopes.
Miscellaneous materials:	For field seaming.
- Adhesive applicators (paint brushes, caulking guns, rollers, etc.). - Liner preparation equipment: clean rags, scrub brushes, scouring pads, pails for solvent, hard surface rollers, seaming support board, heat guns, crayons for marking, dowels for pulling panels, stakes and chalk line, steel measuring tape, scissors and utility knives, electrical extension cords (for heat guns).	
Field crew equipment	For field crew when making seams.
- Safety goggles, solvent resistant gloves, knee pads, respirators, soft soled shoes.	
Portable tent/shed	To allow seaming activities in colder/windy weather.
First aid kit	In case of accidents.
Air compressor	Supply air that might be needed when working with solvents, and for air lance.

Crew size recommendations also depend on the complexity of the installation and the experience of the field crew. If the majority of the crew members are recruited locally, more members may be needed due to lack of experience. At the present time, the trend is toward having installation contractors retain field supervisors who travel from job site to job site. Large jobs where crews perform specific tasks may involve many people.

Field personnel observed at the study sites ranged in number from five to thirty. Generally speaking, the larger the site, the larger were the numbers of field personnel. At all but one location, crew foremen representing the installer were onsite to direct installation. Workers were hired locally as required. The exception was a high density polyethylene installation. In this case, all crew members were employees of the manufacturer and installer.

Liner Placement Procedures

Important considerations that should be followed in placing a membrane liner are as follows:

(1) Follow the design engineer's installation plan showing the location and position of liner panels;

(2) Follow manufacturers' recommended procedures for adhesive system, seam overlap, and sealing to concrete;

(3) Use a qualified installation contractor having experience with membrane liner installation, preferably the generic type of liner being installed;

(4) Plan and implement a quality control program which will help ensure that the liner meets specification and the job is installed per specifications;

(5) Document inspection for review and recordkeeping;

(6) Conduct installation during dry, moderately warm weather (above 45°-60°F depending on material); and

(7) Subgrade should be firm, flat, and free of sharp rocks or debris.

Before moving panels from the storage site to the installation location, a number of tasks must be performed. The anchor trench around the perimeter of the installation should be completed. The dirt excavated from the anchor trench should be raked smooth so that the panels can be unrolled along and parallel to the anchor trench in the width direction. Other things that must be accomplished prior to panel positioning are: (1) the subgrade should be raked smooth or compacted if necessary; (2) there should be no standing water in the impoundment; (3) any concrete structures that must be seamed around should be prepared prior to unrolling any panels; (4) if skirts are to be used around footings on concrete structures, these must be in place prior to the beginning of panel placement; and (5) any outflow or inflow structures or other appurtenances should be in place.

Placement often begins with the unfolding or rolling of the panels in a lengthwise direction. The panels are then unfolded in the width direction, either down the side slope or across the floor. The panels are normally unrolled on the inside of the anchor trench, eliminating the need to move the liner across the trench. The field crew then begins to position or "spot" the panel into its proper location according to the installation plan. As panels are spotted, sand bags are placed along the edges to prevent uplift and subsequent wind damage. The instructions on the boxes containing the liner must be followed to ensure that the panels are unrolled in the proper direction with the correct side exposed for seaming. The panels should be pulled relatively smooth over the subgrade. If the subgrade is smooth and compacted, then the liner should be relatively flat on the subgrade. However, sufficient slack must be left in the material to accommodate any possibe shrinkage due to temperature changes. The amount of slack required depends on the material being installed. Each manufacturer has specific recommendations regarding the amount of slack that should be left during installation.

Unfolding of the panel is normally begun at the anchor trench around the perimeter of the facility. Once the panel is unfolded, it is pulled across the subgrade by the field crew. Workmen grip the panel using dowels which are rolled from the edge of the panel toward the center enough to provide a handle. The edge of the panel is raised and flipped to pump air under the liner. This allows the liner to be pulled into position without damage. This prevents stretching of the materials. Windy conditions may cause serious difficulties for a field crew installing a panel in this manner.

Once the panel is unfolded, the crew positions it properly, providing the necessary slack and overlap of seams. Sandbags are placed along the edges to prevent wind damage. At this point, field seaming crews begin joining the panels together. Table 3 presents a summary of liner placement activities observed at the sites visited during the study.

Field Seaming Procedures

During liner placement, panels must be positioned so the recommended seam overlap will be maintained along the entire edge of the pond. Generally, overlaps were 0.05 m (2 in.) to 0.3 m (1 ft) depending on the material. After correct overlap is achieved, field seaming crews begin inspecting the liner surface to be seamed together. Foreign material, such as dirt, or moisture is wiped off with rags or brooms. A surface oxidation or "cure" has to be removed from certain types of membranes. This is accomplished using a solvent such as trichloroethylene or methyl ethyl ketone. Workers normally wear protective gloves whenever working with these solvents. After removing the surface oxidation, a liberal quanity of solvent is applied. The material is allowed to soften at the surface. Solvent is applied to both surfaces to be seamed together. The two surfaces are pressed together with rollers. A board is often placed under the seam to provide a firm surface for rolling the seam. This procedure is typical for those materials seamed with a solvent. PVC, CSPE and CPE are commonly field seamed with solvents.

Contact type adhesives are used with vulcanized liner materials, such as EPDM. To seam these materials, the surface is prepared with a petroleum distillate, such as fuel oil. Then a contact adhesive is applied to both surfaces. When a tacky surface is produced, the two are folded over and pressure

TABLE 3. SUMMARY OF LINER PLACEMENT ACTIVITIES OBSERVED AT 14 LINED FACILITIES

Facility Type	Mode of On-Site Material Storage	Air Temperature During Installation (°F)	Spotting Techniques	Overlap Width (in.)	Seam Width (in.)	Sealing System	Method to Seal Penetration	Gas Vents	Mode of Final Securing of Liner
Tailings Storage	Cardboard Boxes and Pallet	80-100	Ten-Twelve Man/Panel Machine Assisted	6	3	Solvent	Not Observed	Yes	Vertical Slit Anchor Trench Filled with Soil
Municipal Landfill	Unprotected on Pallets	35-50	4 Man/Panel	2-6	1-2	Direct Contact Heating	Not Applicable	No	Anchor Trench Filled with Soil
Evaporation Pond	Unprotected Rolls	60-80 (Night)	Mechanized Due to Panel	6	1	Heat Gun	Not Observed	No	Half Anchor Trench Filled with Soil
Potable Water Storage	Cardboard Boxes on Pallet	50-65	8 Man/Panel	12	2-4	Solvent	Mastic with Mechanical Seal	No	Batten Strips to Concrete
Brine Storage	Cardboard Boxes on Pallet	80-90	Four-Eight Man/Panel Manual	6	2	Solvent	Mastic with Overlying Weight	No	Vertical Slit Anchor Trench Filled with Soil
Tailings Storage	Cardboard Boxes and Pallet	80-95	Not Observed	6	2	Solvent	Not Observed	No	Vertical Slit Anchor Trench Filled with Soil
Potable Water Storage Concrete	Cardboard Boxes and Pallet	60-95	Six-Eight Man/Panel	4	2	Solvent	Not Observed	No	Vertical Slit Anchor Trench Filled with Concrete
Evaporation Pond	Reflective Material Over Cardboard Boxes	70-95	Six-Eight Man/Panel	4-6	2	Adhesive	Adhesive and Tensioned Band	No	Half Anchor Trench Filled with Soil
Hazardous Material Landfill	Unprotected on Pallets	60-80	Not Observed	4-6	4	Solvent	Not Applicable	No	Half Anchor Trench Filled with Soil
Spill Containment	Cardboard Boxes and Pallet	60-80	Four-Six Man/Panel	4	2	Heat Gun	Adhesion, Mastic Tempered Band	No	Batten Strips to Concrete
Industrial Waste Storage	Burlap Wrapped Rolls	60-70	Six-Eight Man/Panel Machine Assisted	6	4	Adhesive and Lap Sealant	Not Observed	No	Half Anchor Trench Filled with Soil
Municipal Landfill Cover	Unprotected on Palletts	40-60	Six Man/ Panel	2-6	1-2	Solvent with Heat Gun	Solvent with Mechanical Seal	Yes	Half Anchor Trench Filled with Soil
Municipal Wastewater Storage	Cardboard Boxes and Pallet	70-85	Four-Six Man/Panel	4	2	Heat Gun	Not Observed	Yes	Vertical Slit Anchor Trench Filled with Soil
Spill Containment	Unknown	90-95	Three Man/Panel	6	4-6	Adhesive and Lap Sealant	Adhesive with Mechanical Seal	No	Half Anchor Trench Filled with Soil

is applied. Often, a caulking compound is applied at the edge to complete the seam. A cap strip is then applied over the seam.

High density polyethylene liners are bonded together by welding. The automatic machine applies a ribbon of hot HDPE approximately 0.05 m (2 in.) wide between the two liner surfaces which have been preheated. Pressure is applied to the seam at the rear of the unit. The entire machine moves under its own power at a rate set by the worker. This procedure requires a skilled operator to achieve a successful weld. Power is supplied by an onsite portable generator set.

Solvent seaming produces a physical bonding between materials by chemically dissolving the surface layer of the material. Heat seaming simply melts the surface layer of the material to allow the bond to be achieved. A variety of heating devices are used to heat seam membrane liners. Liester guns provide non-contact heating of the material. Direct contact heating elements are also used. Heat seaming is difficult and does not necessarily provide a superior field seam compared to other available methods. Direct contact heat seaming was observed at only one site visited during this study.

Sealing Around Structures/Penetrations

Various approaches to bonding liner material to concrete, metal, or plastic structures were observed at the majority of sites visited. Generally speaking, where the structures were the same material as the liner, bonding appeared to be a simpler task requiring fewer steps. High density polyethylene and PVC liners can be bonded directly to pipes made of the same material. However, basic resins used to make these materials may have different thermo-expansion characteristics. Therefore, the installer should be sure they can be bonded together prior to installation.

The design of most installations visited included some type of structure that penetrated the liner system. These structures included inlet/outlet pipes, concrete support piers, drain flanges, gas vents, and concrete emergency overflow abutments. For those cases where liner material and structure material were incompatible, several approaches to sealing were observed. For sealing liner material to concrete, a combination of a mechanical and mastic system was used at one site. Anchor bolts were placed into the concrete to secure steel strips. The steel strips were placed over the liner. Between the liner and the concrete, a mastic was applied to make a tight seal. A mastic recommended by the liner manufacturer that is compatible with the membrane and the waste was chosen for this purpose.

Liner materials and structural materials, such as concrete, are also joined using a combination of mechanical devices and boots made of the liner material. At one location, an inlet pipe made of fiberglass was isolated by the use of a boot constructed in the field with a mechanical clamp sealing off the pipe to fluid movement. The boot was bonded to the side slope of the impoundment to complete the seal. For a large number of penetrations, the installer generally will work with a fabricator to construct boots in the factory rather than in the field.

All polymeric liners are anchored at the berm or top of a landfill or surface impoundment. The edge of the liner is placed in a trench typically one foot wide and one foot deep. A backfill of earth or concrete secures the edge in the trench.

Quality Assurance/Quality Control

With respect to geomembrane liner system installation, quality assurance/quality control (QA/QC) activities should be implemented to increase the confidence that the liner system was installed as specified. The more extensive the QA/QC program, the higher degree of confidence the owner would likely have that the system will function as intended.

Observed activities in the field which were intended to be QA/QC procedures ranged from sampling field and factory seams from every panel placed to visual inspection of field seams. At two sites, independent third party contractors provided checks of all installation activities and prepared a summary of compliance with installation plans and procedures. These contractors were onsite during the entire installation period. At one of these sites, samples of each seam were taken and sent to a laboratory for testing. Laboratory results were reviewed by the QA/QC contractor. If the samples did not meet minimum requirements, the seam was remade. The decision to remake the seam was not subject to interpretation. If problems were identified, resolution was the responsibility of the QA/QC contractor. At both of these sites, the seam testing performed was destructive testing in the sense that the sample was cut from the field seam. This method of testing meant that for each field sample taken, a patch was installed in the liner system. Both QA/QC inspectors believed the benefits gained from sample testing outweighed the drawbacks of having to patch an equal number of cuts in the liner.

Table 4 presents a summary of various QA/QC elements observed at the sites visited during this project. Personnel were assigned and wholly dedicated to the job of inspecting the quality of work at seven sites. As previously indicated, the owners of two sites contracted third parties to conduct QA/QC onsite. At the five other sites, QA/QC inspection was performed by either the installer's personnel or the manufacturer's personnel. The installation field chief provided QA/QC at the other seven sites.

Subgrade inspection was performed at every site, since this is critical to the success of a liner system. Testing to determine adherence to density requirements was performed at eight sites. Two of the remaining six involved concrete subgrades, and were not tested for that reason. No testing was performed at the remaining four sites.

The quality of the liner material in terms of visual appearance was determined at every site at the time the material was placed onto the subgrade. Quantitative, non-destructive testing was performed at two sites. Methods used were ultra-sonic testing and tensile testing of field seams. Destructive testing of seam samples was performed at two sites which were previously discussed.

TABLE 4. SUMMARY OF FIELD QUALITY ASSURANCE OBSERVED AT 14 LINED FACILITIES

Facility Type	Wholly Dedicated Inspection Personnel	Subgrade Inspection	Subgrade Testing	Liner Material Exam	Field Seam Examination			
					Visual Exam	Physical Testing		
						Qualitative	Quantitative	
							Non-Destructive	Destructive
Tailings Storage	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Municipal Landfill	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Evaporation Pond	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Potable Water Storage	No	Yes	No	Yes	Yes	Yes	No	No
Brine Storage	No	Yes	Yes	Yes	Yes	Yes	No	No
Tailings Storage	No	Yes	Yes	Yes	Yes	Yes	No	No
Potable Water Storage	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Evaporation Pond	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Hazardous Materials Landfill	No	Yes	Not Known	Yes	Yes	Yes	No	No
Spill Containment	Yes	Yes	No	Yes	Yes	Yes	No	No
Industrial Waste Storage	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Municipal Landfill Cover	Yes	Yes	No	Yes	Yes	Yes	No	No
Municipal Wastewater Storage	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Spill Containment	No	Yes	No	Yes	Yes	No	No	No

Soil Covers

Several manufacturers of geomembrane liners suggest that at least a 0.15 m (6 in.) soil cover be placed over the liner after installation is completed. This practice is recommended to provide a protective barrier against weathering, mechanical, and other environmental damage. Ultraviolet light for extended periods can degrade certain polymeric materials. Most liners made of PVC are especially susceptible to UV light. Generally, PVC manufacturers suggest placing a soil cover over material exposed to sunlight for extended periods (>6 months). A soil cover also minimizes mechanical damage from landfilling operations, wave action, freeze/thaw cycles, vandalism, hail, and wildlife.

Soil covers were installed over the liner systems at seven of the fourteen sites. Three of these sites specified PVC geomembranes which required a soil cover for ultraviolet light protection. The remaining four sites installed covers for protection against heat or mechanical damage. Equipment to accomplish this task included bulldozers, pan scrapers, and front end loaders. Soil covers were not installed at seven sites. Manufacturers of these materials did not require soil covers as a condition of material warranty.

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